Report for 2005NE87B: Quantification of Stream-aquifer Connection and its Implication for Modeling Surface Water-Groundwater Interactions

Publications

- Articles in Refereed Scientific Journals:
    - Chen, X.H., and L. Shu, 2006. Groundwater evapotranspiration captured by seasonally pumping wells in river valleys. Journal of Hydrology 318: 334-347.
    - Wen, F. J. and X. H. Chen, 2006. Evaluation of the impact of groundwater irrigation on streamflow depletion in Nebraska. Journal of Hydrology (Available online February 24, 2006).
    - Chen, X. H., C. Cheng, M. Burhach, 2006. Streambed conductance estimated for the Platte River in Southeast Nebraska. Journal of Hydrology (in review).
    - Chen, X. H., 2006. Groundwater hydrology of a river-alluvial aquifer zone in south-central Platte Valley, Nebraska. Journal of Hydrology (revision required).

Report Follows

Problem and research objectives: Poor understanding of the hydrologic relationship between streams and their surrounding aquifers can be economically and ecologically very costly. Better management of stream water and groundwater requires a full understanding of the hydrologic relationship between stream and aquifers. This project seeks to use new methodologies for quantifying stream-aquifer connections by analyzing the hydraulic conductivity (K_v) and stratification/thickness (*M*) of streambed sediments. The study area is in the Platte River of south-central Nebraska where streamflow depletion has been a concern, affecting proper habitat for four endangered and threatened species.

Methodology: In-situ permeameter tests were conducted in the Platte River to measure the vertical hydraulic conductivity of streambed across the river channels. Electrical conductivity (EC) logs of streambed sediments in the channel of the Platte River were generated by direct-push methods. Direct-push methods employ both static force and percussion to advance sampling and logging tools into the subsurface. A Geoprobe¨ Systems SC400¨ soil conductivity probe consisting of a four-electrode Wenner array with an inner-electrode spacing of 2 cm was used in this investigation. EC logs show sediment layers of low-permeability for evaluation of the thickness of streambed sediments. The direct push methods were also used to collect sediment cores in the Platte River and the vertical hydraulic conductivity of these cores were determined by conducting permeameter tests on these cores in laboratory. Computer source codes using the Galerking finite-element method was developed to simulate the interactions of stream-aquifer systems and to inversely calculate hydraulic parameters of streambed sediments.

Principal findings and significance: Sediments in the upper 50-to 90-cm streambed of the Platte River consist largely of sand and gravels and contain less than 0.2% of silt. Because of this low percentage of silt, clogging of the streambed at the channel surface was not observed. Such a sediment composition results in a large hydraulic conductivity. The average vertical hydraulic conductivity (*K*v) values of the top 50-cm sediments along two transects are 32.8 and 48.8 m/d, respectively. But, the *K*v for the sediments immediately under the top 50-cm streambed have smaller values, with an average of 24 and 33.4 m/d, respectively, for the two sites. The *K*v values of channel sediments determined from sediment cores taken by the direct-push method also show a tendency to decrease with the depth of the sediments.

Electrical conductance logs generated in the channel sediments of the Platte River suggest that low-hydraulic-conductivity layers can occur in some river segments but are absent in other segments. For the upper 10-m channel sediments, there are two major types of sedimentary structures: Type-I channel sediments consist of sand and gravel, type-II channel sediments contain thin or thick silt-clay layers occurring several m below the channel surface, which are interbedded with sand and gravels. The *K*v values of silt-clay layers (around 0.01 m/d) can be several orders of magnitude smaller than those for the sand and gravels. If occurring, these LHC layers can largely reduce the hydraulic connectedness between stream water and groundwater. The streambed thickness for several sites with Type II channel sediments is about 4 m. Selection of streambed thickness (*M*) for Type-I channels may depend on a number factors, including well depth and study objectives. Streambed conductance values may have a difference of several orders of magnitude between one river segment and another, and they thus can give a large difference in the calculation of water exchange between the river and the groundwater.

The computer programs can generate flow nets over a vertical profile of stream-aquifer systems for examination of flow dynamics. A number of hydrologic factors affect groundwater flow dynamics near a river. An aquifer with lower vertical hydraulic conductivity reduces baseflow to streams and forces more water to flow laterally beneath the river. When an aquifer is thin, the groundwater flow in the whole thickness can be affected by the hydrologic condition in the stream and by the riparian vegetation. As the thickness increases, the deeper part of groundwater is less likely to be affected by surface hydrologic conditions. Groundwater ET by vegetation in riparian zones intercepts baseflow and can bring water in the deeper part of the aquifer to the water table. The ET can also induce a large volume of stream infiltration. Consumption of groundwater and stream water by ET results in complex patterns of streamlines in riparian zones. This may lead to some difficulties in interpretation of water quality data.